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SUBJECTIVE RESPONSE TO COMBINED NOISE AND VIBRATION DURING FLIGHT OF A LARGE TWIN-JET AIRPLANE

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16. Abstract

This report presents the results of a study in which an NASA twin-jet airplane was used to obtain controlled noise and vibration environments during flight while obtaining subjective responses from 13 passenger-subjects (6 females and 7 males). Subjective ratings of overall comfort, comfort when considering only vibration, and comfort when considering only noise were obtained during times of different vibration and noise environments. Passenger-subjects were able to distinguish and rate noise better than vibration in this study. In addition, there was a statistically significant difference in ratings of ride comfort due to both sex type and flight experience. Males rated flying discomfort much more severely than females when rating the overall ride and the ride when considering only the noise environment. Experienced passengers also rated the overall ride to be more uncomfortable than inexperienced passengers.

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SUMMARY

Thirteen passenger-subjects were asked to rate their comfort associated with noise and vibration during a 1-hour flight aboard an NASA twin-jet airplane. The airplane was flown in a straight, horizontal path at a 3962-meter (13 000-foot) altitude. A range of vibration and noise levels was obtained by varying the thrust, the forward speed, and the position of the landing gear and drag brakes. The subjects were asked to rate designated 1-minute segments of the flight. The passenger-subjects' ages ranged from 18 to 48 years, weight from 54 to 84 kg (118 to 185 lb), and flight experience from first flight to many flights. Seven subjects were males and six were females; nine were professionals, three were students, and one was a homemaker.

For this flight, the noise and vibration levels were essentially independent of each other. For constant vibration level, good correlations were obtained between the vibration ratings and noise ratings, vibration ratings and noise levels, and noise ratings and noise levels. However, at constant noise levels, although the noise rating correlated well with vibration rating, both the noise rating and the vibration rating showed poor correlations with vibration level. Passenger-subjects were able to distinguish and rate noise better than vibration.

There was a statistically significant difference in ratings of ride comfort due to both sex type and experience in flying as passengers. Males rated flying discomfort much more severely than females when rating the overall ride and the ride when considering only the noise environment. Experienced passengers rated the overall ride more severely than inexperienced passengers.

INTRODUCTION

The problem of vibration and audible noise in aircraft has always affected the feeling of well-being, that is, comfort or discomfort, while flying. The solution to the problem is compounded by both the paucity of in-flight vibration and noise measurements and by the lack of subjective measurements with a controlled environment. Although few data on subjective responses are published for actual aircraft flights (see, for example, ref. 1), some

studies have been made by using airborne or ground-based simulators. (For example, see refs. 2, 3, and 4.) A bibliography on ride-comfort studies is published in a recent AGARD paper (ref. 5), and a number of recent studies are reported in reference 6. One study conducted by the University of Virginia used paying passengers in commercial aircraft (ref. 1). However, only limited questionnaires could be used with these passengers and there was no control of the noise or vibration of the aircraft. A second University of Virginia study (ref. 2) utilized the NASA Jetstar airplane with the GPAS (General Purpose Airborne Simulator) system in which only two test subjects could be flown at one time. The ground-based simulator tests (refs. 3 and 4) utilized from two to six subjects in a controlled vibration environment, but the feeling of flying at an altitude of thousands of meters in an airplane could not be simulated. The current flight study provided realism by utilizing a commercial-type twin-jet airplane; the noise and vibration environment was varied by changes in the airplane configuration.

In the course of using ground-based simulators, investigators have looked for effects of sex type and flight experience on comfort ratings. Reference 4 showed that sex type had negligible effect, whereas data from reference 7 showed that males rated more severely than females in the rms (root-mean-square) vibration range below 0.04g; that is, the same ride was rated more uncomfortable by males. The effect of flight experience was shown to be negligible in references 3 and 7. The subjects selected for the current study included both males and females as well as experienced and inexperienced passenger-subjects.

The current study consisted of recording subjective responses of a group of males and females while flying in the NASA twin-jet airplane during the various noise and vibration conditions created while the airplane was in straight and level flight. For each condition the noise and vibration environment was also recorded. The main objective of this study was to obtain and correlate flight objective data and subjective data, from which the effect of noise and vibration on human-comfort response would be determined. Secondary objectives were to study the effects of sex type and flight experience on the response rating of the passengers.

EXPERIMENTAL DESIGN

The NASA twin-jet airplane (fig. 1) was used for obtaining flight objective and subjective measurements. Some of the physical characteristics of the airplane are listed in table I. Vibration and noise measurements were recorded throughout the flight. Subjective responses were obtained during 13 1-minute segments during level flight at a 3962-meter (13 000-foot) altitude. The weather was clear with no apparent clear-air turbulence. The noise and vibration environment was varied by changing engine thrust, wheel position (retracted or extended), drag-brake position, and airspeed. The 13 passenger-

subjects consisted of 7 males and 6 females whose ages ranged from 18 to 48 years and had flight experience ranging from first flight to having flown over 160 934 km (100 000 miles).

After each segment of flight had stabilized (1 to 2 minutes), the passenger-subjects were asked to consider 1 minute of flight and then to complete the three-part questionnaire shown in table II. The first part consisted of rating the overall ride by utilizing the adjectives "very comfortable," "comfortable," "acceptable," "uncomfortable," and "very uncomfortable." For later analysis, these adjectives were replaced by numbers 1, 2, 3, 4, and 5, respectively, and were called overall ratings R_o. The other two parts of the questionnaire concerned rating the noise and vibration in terms of comfortable and uncomfortable on a 5-point scale where 1 was at the most comfortable end of the scale and 5 was at the most uncomfortable end of the scale. These noise comfort and vibration comfort ratings were designated by R_n and R_v, respectively.

After completion of the 13 flight segments, each passenger-subject was requested to complete a second questionnaire shown in table III. The purpose of this questionnaire was to obtain both demographic data on the passenger-subjects and to obtain their reactions to various ideas and conditions. A summary of the responses to this questionnaire is given in appendix A.

The seating locations of the passenger-subjects and the placement of the instrumentation are shown in figure 2. The passenger-subjects were located both behind and in front of the trailing edge of the wing, and the vibration-measuring equipment was located near the center of gravity of the airplane. All seats in this airplane are shown in figure 2; the airplane was not configured as the typical commercial vehicle with reference to the number of seats, but the rest of the interior appeared as a commercial airplane in regard to paneling, lighting, and other features.

The instrumentation consisted of measuring and recording equipment for vibration, noise, and temperature. Vibrations were measured by using accelerometers powered by batteries, with all being enclosed in portable containers as shown in figure 3. The outputs of the accelerometers were recorded on six FM channels of a seven-channel portable flight tape recorder. The frequency response of the vibration-measuring system was from 0 to 25 Hz. Two sets of three orthogonal accelerometers were used. Additional details of this system are given in reference 8. The noise was measured on a sound-level meter and was recorded directly on the seventh channel of the tape recorder. The temperature of the airplane was measured with a laboratory thermometer and was manually recorded on a data sheet. The temperature was maintained essentially constant at about 24° C (75° F) by the air-conditioning system of the airplane.

RESULTS AND DISCUSSION

The results of this investigation are shown both graphically and in tabular form. The measured noise and vibration environments are given in table IV and shown in figure 4. The averages for the ratings R_o, R_v, and R_n for all subjects are given in table IV; for males and females, in table V; and for experienced and inexperienced passenger-subjects, in table VI. These data are shown in figures 5 to 12. Typical standard deviations of subjective ratings for a given test condition were of the order of ±0.9.

Effect of Noise and Vibration

To study the individual effect of noise and vibration, it is first necessary to show that little or no correlation exists between noise and vibration. Thus, if the vibration levels always increased as the noise increased, there would be a high degree of correlation and it would be impossible to correlate a rating with one and not the other. The measured noise and vibration data from the flight are shown in figure 4. Since the measured lateral vibrations were considerably less than the measured vertical vibrations, all comparisons will be made by considering only vertical vibrations in this paper. It can be seen that little correlation exists between noise and vibration during this flight. Thus, it may be possible to show which environment affects the ratings, or at least to show how the passenger-subjects distinguish and rate the noise and vibration environments.

To study the individual effects, the data of figure 4 were separated into groups of essentially constant noise levels (in dB(A)) and rms vibration levels (in g units). The "constant" group vibration levels to be considered are $g_{rms} = 0.0344 \pm 0.0059$, 0.0498 ± 0.0051, and 0.1095 ± 0.0066 indicated by acceleration groupings a_1, a_2, and a_3, respectively, in figure 4. The "constant" group noise levels to be considered are 82.5 ± 1.5 dB(A), 88 ± 2 dB(A), and 93 ± 2 dB(A) indicated by the noise groupings n_1, n_2, and n_3, respectively, in figure 4.

It is first shown that the vibration ratings R_v are well correlated ($r = 0.854$; see appendix B for definition of r) with the noise ratings R_n for all the data obtained (shown in fig. 5 and listed in table IV). For the three grouped vibration levels, the trend of R_v increasing with increasing R_n is also indicated. Thus, it is necessary to observe the trend of the ratings as a function of the measured environment. It should be noted that the overall ratings R_o closely follow the vibration ratings R_v (table IV); and since factors other than noise and vibration may have entered into R_o, there will be little discussion of R_o.

The ratings due to vibration are shown as a function of measured noise environment (in dB(A)) in figure 6. Collectively, the data show a correlation coefficient $r = 0.622$ between vibration rating and noise level. At the medium and high vibration levels, an

increase in noise shows an increase in vibration ratings. (Number 5 represents maximum discomfort.) At the low vibration level, group a_1, there appears to be no trend of vibration rating compared to the noise environment. Based on the higher vibration levels, groups a_2 and a_3, it may be concluded that the noise environment does affect the vibration rating.

The ratings due to noise R_n as a function of noise level (in dB(A)) while holding acceleration constant are shown in figure 7. The data have a high correlation coefficient ($r = 0.715$), and at each vibration level, the trend of increased numerical rating with increased noise level is shown; thus, this noise environment is an excellent indicator of comfort due to the noise environment.

To observe the effects of vibration, the data are replotted for three "constant" noise levels. The noise rating is shown as a function of vibration rating in figure 8. The correlation coefficient is the same ($r = 0.854$) as in figure 5. (The same data are plotted differently.) The vibration rating R_v is shown as a function of rms acceleration level in g units in figure 9. There is little correlation between R_v and acceleration level ($r = -0.401$). The data of figure 9 indicate that passenger-subjects do not sort out vibration or rate comfort due to vibration very well on this airplane. Some other factor, specifically the noise environment as shown in an earlier figure, is causing or interacting with the comfort rating due to vibration.

The noise comfort rating R_n is shown as a function of vibration (acceleration) level for constant noise levels in figure 10. As might be expected, little correlation exists between noise rating and vibration level ($r = -0.219$).

In order to visualize the effects of noise and vibration better, the data for the center groupings of vibration and noise levels have been extracted from figures 5 to 10 and are shown in figure 11. The correlation coefficients (r) for each set of data are shown above each plot. Note the high correlation coefficients for both R_v and R_n as functions of noise level for constant g_{rms}. In the lower half of the figure, note the very low (one is negative) coefficients for R_n and R_v as functions of vibration level where the noise is constant. Thus, although R_v and R_n are correlated to each other, they correlate well only with noise environment and not with vibration environment on this airplane. It is apparent that the passenger-subjects can distinguish and rate noise better than they can distinguish and rate vibration in this airplane.

A comparison of how males and females rate comfort in this airplane is indicated in table V and figure 12. The ratings R_n, R_v, and R_o are compared between male and female passengers on this flight. The 45° line on each plot divides the ratings as follows: If all data fall on this line, the males and females are rating the flight segments the same; that is, they are giving the same rating for each flight segment. If the data fall above the 45° line, males are rating more severely; and if the data fall below the line, females are rating more severely. The t-tests (see appendix B) were made at the 0.05 level of

significance to determine whether the data showed a statistically significant trend (or occurred by chance). From figure 12 and table V, it is seen that males rate the ride more severely than females throughout the range of vibration and noise levels for comfort ratings due to noise R_n and for overall comfort ratings R_o. However, it should be noted that only a small sample of passenger-subjects was used in this study. These results are somewhat different from those described in reference 7 where it was shown that males rated the ride more severely than females in the rms vibration range below 0.04g, and then a reversal occurred in that females rated more severely than males at rms vibration levels greater than 0.055g. These latter results were also based on a small sample of passenger-subjects.

Effect of Flight Experience

The effect of flight experience is shown in figure 13 and table VI where the ratings by experienced subjects are compared with those of inexperienced subjects. The passenger-subjects with four or more flights were considered experienced. It is shown that experienced subjects rate more severely than inexperienced subjects for overall ratings R_o. For ratings due to vibration and noise, no statistically significant difference was found at the 0.05 level.

Any further breakdown of subjects according to sex and flight experience makes for a very small sample size and, consequently, low reliability. Results will not be discussed here but can be found in appendix C, which includes a table indicating which comparisons have statistical significance at the 0.05 level.

Typical noise and vibration spectra are given in appendix D. For each condition of maximum thrust (including cruise), landing gear extended, and landing gear and speed brakes extended, both the acoustic and vibration spectra had the same shape, although their levels differed.

CONCLUDING REMARKS

Thirteen passenger-subjects were asked to rate their comfort associated with noise and vibration during a 1-hour flight aboard an NASA twin-jet airplane. The airplane was flown in a straight, horizontal path at a 3962-meter (13 000-foot) altitude. A range of vibration and noise levels was obtained by varying the thrust, the forward speed, and the position of the landing gear and drag brakes. The passenger-subjects' ages ranged from 18 to 48 years, weight from 54 to 84 kg (118 to 185 lb), and flying experience from first flight to many flights. Seven subjects were males and six were females; nine were professionals, three were students, and one was a homemaker.

For this flight, the noise and vibration levels were essentially independent of each other. For constant vibration level, good correlations were obtained between the vibration ratings and noise ratings, vibration ratings and noise levels, and noise ratings and noise levels. However, at constant noise levels, although the noise rating correlated well with vibration rating, the noise rating and the vibration rating both showed poor correlations with vibration level. Thus, during this flight passenger-subjects were able to distinguish and rate noise better than vibration.

Although only a small number of passenger-subjects were utilized, there was a statistically significant difference in ratings of ride comfort due to both sex type and experience in flying. Males rated flying discomfort much more severely than females when rating the overall ride and the ride when considering only the noise environment. Experienced passengers also rated the overall ride more severely than inexperienced passengers.

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August 2, 1976

APPENDIX A

RESULTS OF SECOND QUESTIONNAIRE SHOWN IN TABLE III

1. Age: 18 to 48 years; median: 28 years
   Weight: 54 to 84 kg (118 to 185 lb); median: 62 kg (137 lb)
   Height: 1.6 m (5' 3") to 1.8 m (5' 11.5"); median: 1.7 m (5' 7")

2. Sex: Seven males; six females

3. Occupation: Nine professionals; three students; one homemaker

4. Income: From less than $10,000 to over $30,000

5. Purpose of trip: 92 percent business; 8 percent pleasure

6. Flight experience: 8 percent none; 23 percent from 1 to 3 previous flights; 69 percent greater than 4 flights

7. Attitude toward flying:* 91 percent liked it; 9 percent disliked it

8. Importance of factors:*

	None, percent	Moderate, percent	Very, percent
(a) Trip cost	18	36	46
(b) Time-saving	18	18	64
(c) On-time arrival	18	55	27
(d) Onboard services	46	46	8
(e) Ride comfort	0	27	73
(f) Convenience (door-to-door)	27	56	27
(g) Ability to read or write	18	64	18

9. Time spent:*

	None, percent	Some, percent	Most, percent
(a) Reading	73	18	9
(b) Writing	36	55	9
(c) Talking	9	55	36
(d) Looking out window	0	45	55
(e) Dozing	55	45	0
(f) Thinking	9	73	18
(g) Drinking or eating	82	18	0

*Based on respondents.

10. Overall reaction to complete flight:

Very comfortable, percent	8
Comfortable, percent	92
Neutral, percent	0
Uncomfortable, percent	0
Very uncomfortable, percent	0

11. Feelings about environments:*

	Not uncomfortable, percent	Somewhat uncomfortable, percent	Very uncomfortable, percent
(a) Lighting	100	0	0
(b) Pressure (on ears)	67	33	0
(c) Noise	25	67	8
(d) Odors (other than tobacco)	92	8	0
(e) Presence of tobacco smoke	92	8	0
(f) Temperature	75	25	0
(g) Ventilation	92	8	0
(h) Workspace	92	8	0
(i) General vibration	85	15	0
(j) Sudden jolts	85	15	0
(k) Bouncing	75	25	0
(l) Back-and-forth motion	92	8	0
(m) Side-to-side motion	85	15	0
(n) Sudden descents	92	8	0
(o) Turning	55	36	9

12. Physical comforts of seat:*

	Agree, percent	Disagree, percent	Strongly disagree, percent
(a) Enough legroom	100	0	0
(b) Satisfactory firmness	100	0	0
(c) Wide enough	83	17	0
(d) Satisfactory shape	83	17	0
(e) Satisfactory adjustment	75	25	0

13. Specify seat location: see figure 2 of paper

*Based on respondents.

14. After this flight I would –

(a) Be eager to take another flight,* percent	83
(b) Take another flight with confidence, percent	17
(c) Take another flight, but with some doubt, percent	0
(d) Perfer not to take another flight, percent	0
(e) Not take another flight, percent	0

15. Have you taken airsickness medication previously? . . . . 100 percent no
This flight? . . . . 100 percent no
Did you experience any symptoms of airsickness on this flight? . . 100 percent no

*Based on respondents.

APPENDIX B

DEFINITIONS OF r AND t

The correlation coefficient r (see pp. 163 to 168 in ref. 9) gives an indication of the deviation of a set of data from a straight line. A value of 0 indicates no correlation or a complete deviation from a straight line. A value of ±1 indicates that all samples fall on a straight line. Thus, r is defined as

$$r = \frac{\sum_{i}^{n} \left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{nS_X S_Y}$$

Omitting indexes and rewriting gives

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

where x represents one set of data and y represents the other, S_X and S_Y are estimates of the standard deviations of the variables, and n is the number of observations.

The paired t-test is used to test an hypothesis that a sampling of data occurred because of a treatment rather than by chance, particularly when extraneous factors cause a significant difference in means. A t-value is calculated and compared to a value in a set of tables based on degrees of freedom and confidence levels. Since any effect, either positive or negative, would be accepted, a two-tailed t-value is compared to the calculation. Thus, for the data in this paper, for 12 degrees of freedom (13 treatments) at the 0.05 level of significance, the value of t from the table in reference 9 (p. 393) is 2.179. If the calculated value of t is greater than 2.179, then the data show a significant change due to the treatment. Thus, t is calculated as follows (see ref. 10, pp. 115 to 127):

$$t = \frac{\bar{d}}{s^2/\sqrt{N}}$$

where $\bar{d} = \bar{X}_1 - \bar{X}_2$ is the difference of the means of the populations, s^2 is the variance of the differences, and N is the number of paired observations.

APPENDIX C

EFFECT OF SEX TYPE AND FLIGHT EXPERIENCE

In this appendix the following tables and figures show additional effects of sex type and experience in flying as a passenger in an airplane. In table CI showing paired ratings, the averages of the males and females with and without flight experience are given. In table CII showing statistical significance, the computed "t-values" are shown as well as whether the data plotted in figures C1 and C2 show statistical significance at the 0.05 level. In these figures, a flagged symbol represents a duplicate data point. Although these data tend to confirm the conclusions pertaining to sex type and experience, the data sample is so small that no conclusions should be drawn from these data.

TABLE CI. - TABLE OF PAIRED RATINGS

rms vertical vibration, g units	Experience		Inexperience		Experience		Inexperience		Experience		Inexperience	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
	Noise rating, R_n				Vibration rating, R_v				Overall rating, R_o			
0.0285	3.7	2.7	2.0	2.3	2.2	2.0	2.0	2.3	3.0	2.0	2.0	2.0
.0312	2.5	2.0	2.0	2.3	2.5	1.3	1.0	2.0	2.2	1.7	2.0	1.7
.0316	3.8	2.7	3.0	3.3	2.8	2.0	2.0	2.7	3.6	2.0	3.0	2.3
.0319	3.8	2.7	3.0	3.7	2.8	1.7	2.0	3.0	3.7	2.3	2.0	2.7
.0403	4.3	3.0	3.0	3.7	3.0	2.0	2.0	2.7	3.8	2.0	3.0	2.0
.0447	2.8	2.3	3.0	2.3	2.8	3.0	2.0	2.0	3.2	2.7	3.0	3.0
.0448	3.8	3.7	3.0	4.0	2.8	2.7	2.0	3.3	3.4	2.7	2.0	3.3
.0486	1.8	1.3	2.0	1.3	1.5	1.0	1.0	1.3	2.0	1.0	2.0	2.0
.0506	2.8	2.3	1.0	2.7	2.3	2.0	1.0	2.0	2.5	2.7	2.0	2.7
.0536	4.5	3.3	4.0	4.3	2.8	3.0	2.0	2.3	3.7	3.6	3.0	3.3
.0549	3.8	3.0	4.0	4.0	3.0	3.7	3.0	3.3	4.2	3.3	4.0	3.7
.1029	1.8	2.0	2.0	1.3	1.6	2.0	1.0	1.0	1.8	2.7	2.0	1.7
.1161	3.5	3.0	3.0	2.7	2.2	1.7	2.0	1.7	3.3	2.3	2.0	2.7

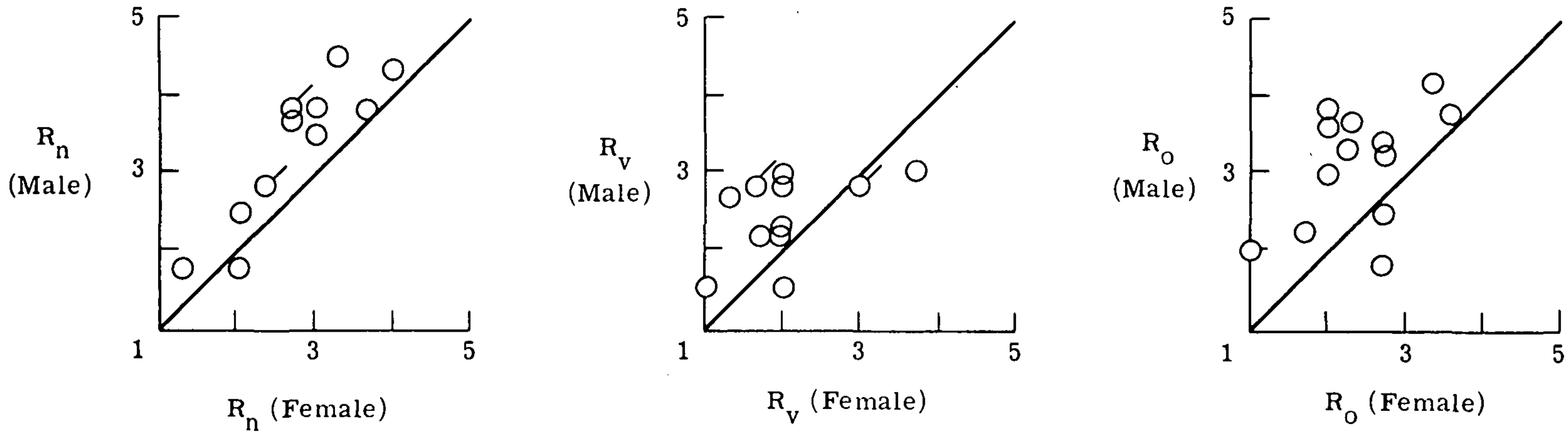
APPENDIX C

TABLE CII.- TABLE OF STATISTICAL SIGNIFICANCE AT THE 0.05 LEVEL*

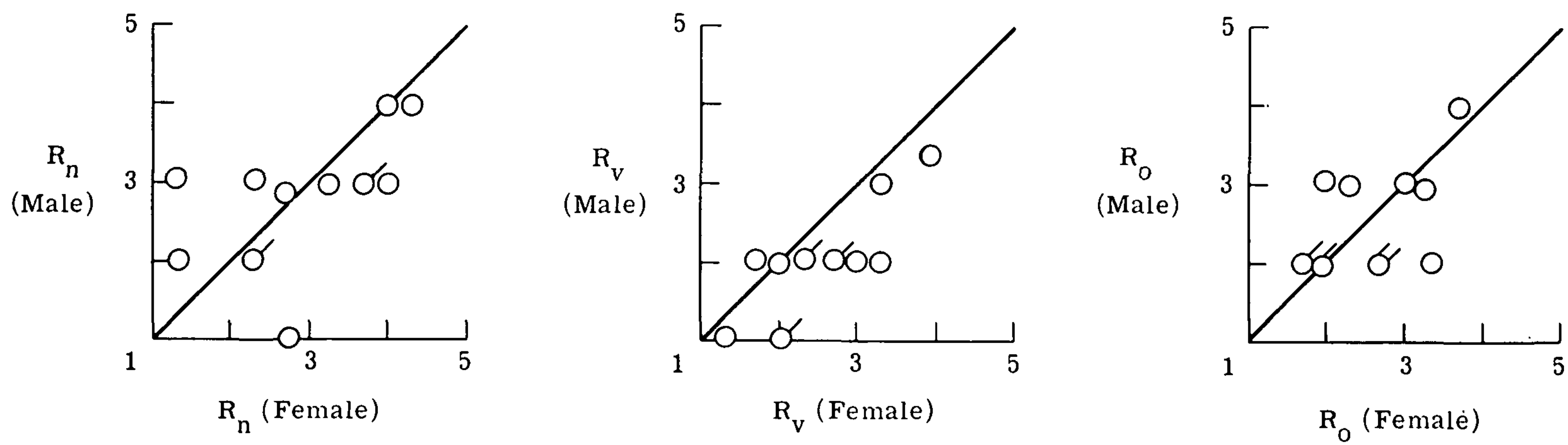
$[|t| > 2.179]$

Statistical rating	t-value	Significance	
		Yes	No
Noise rating			
Exp. males to inexp. males	-3.14	✓	
Exp. females to inexp. females	1.93		✓
Exp. males to exp. females	-5.52	✓	
Inexp. males to inexp. females	1.12		✓
Inexp. males to exper. females	.42		✓
Exper. males to inexp. females	-3.23	✓	
Vibration rating			
Exp. males to inexp. males	-5.94	✓	
Exp. females to inexp. females	.58		✓
Exp. males to exp. females	-1.87		✓
Inexp. males to inexp. females	3.81	✓	
Inexp. males to exper. females	-2.71	✓	
Exper. males to inexp. females	-1.89		✓
Overall rating			
Exp. males to inexp. males	-4.03	✓	
Exp. females to inexp. females	1.21		✓
Exp. males to exp. females	-3.51	✓	
Inexp. males to inexp. females	.48		✓
Inexp. males to exper. females	-.41		✓
Exper. males to inexp. females	-3.53	✓	

*See figures C1 and C2.

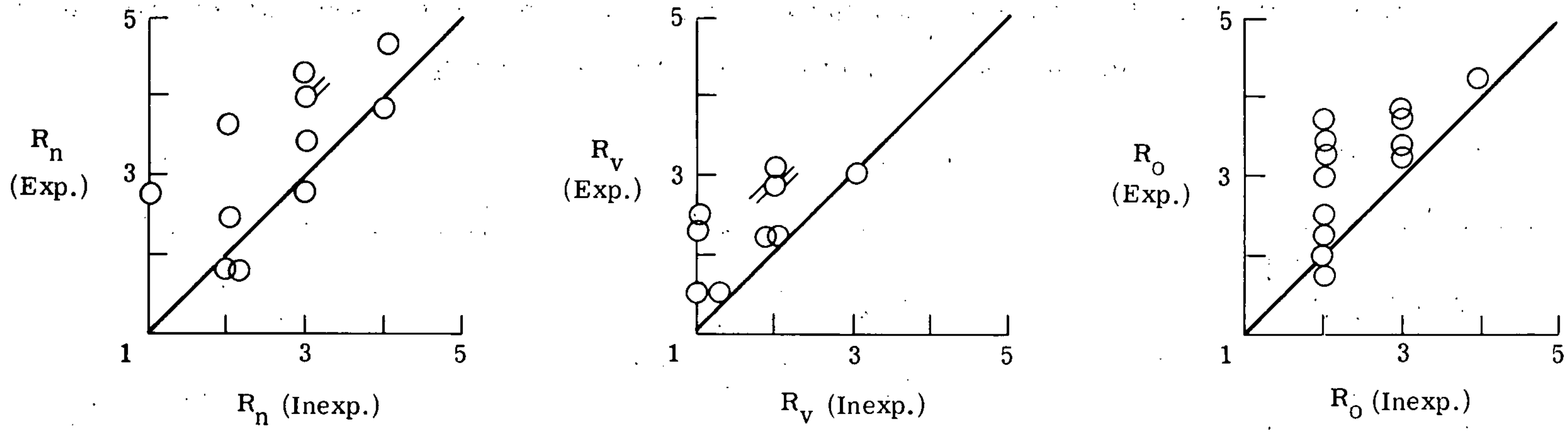


(a) Experienced passengers with four or more flights.

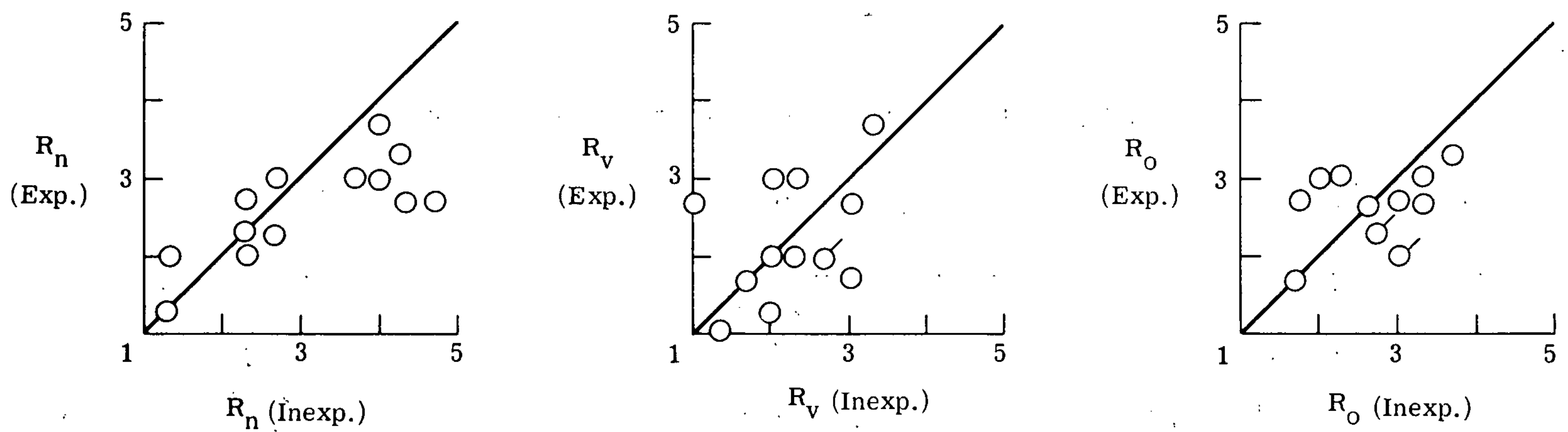


(b) Inexperienced passengers with fewer than four flights.

Figure C1.- Comparisons of male and female ratings. Each flag on a symbol represents a duplicate data point.



(a) Male.



(b) Female.

Figure C2.- Comparisons of subject ratings with and without flight experience. Each flag on a symbol represents a duplicate data point.

APPENDIX D

TYPICAL VIBRATION AND NOISE SPECTRA

In this appendix figure D1 shows typical vibration spectra for cruise and maximum cruise, landing gear extended, and landing gear and speed brakes extended. Each curve is representative of the flight condition shown, with all having similar shapes but different amplitudes. Figure D2 shows typical unweighted sound-pressure level conditions. Although the three spectra are not alike, the repetitions of each flight segment did result in similar spectra, although at somewhat different levels.

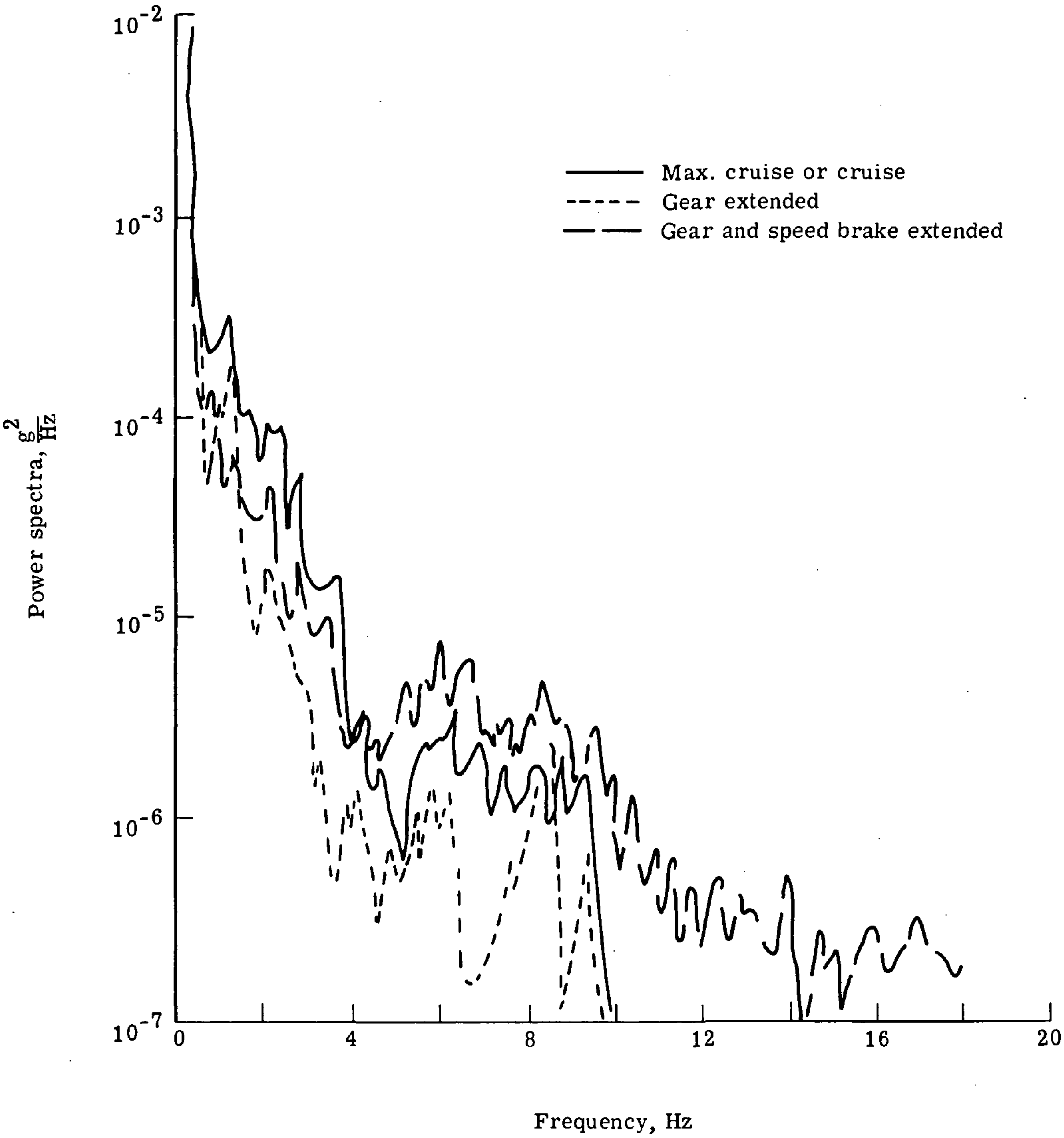


Figure D1.- Typical vibration spectra.

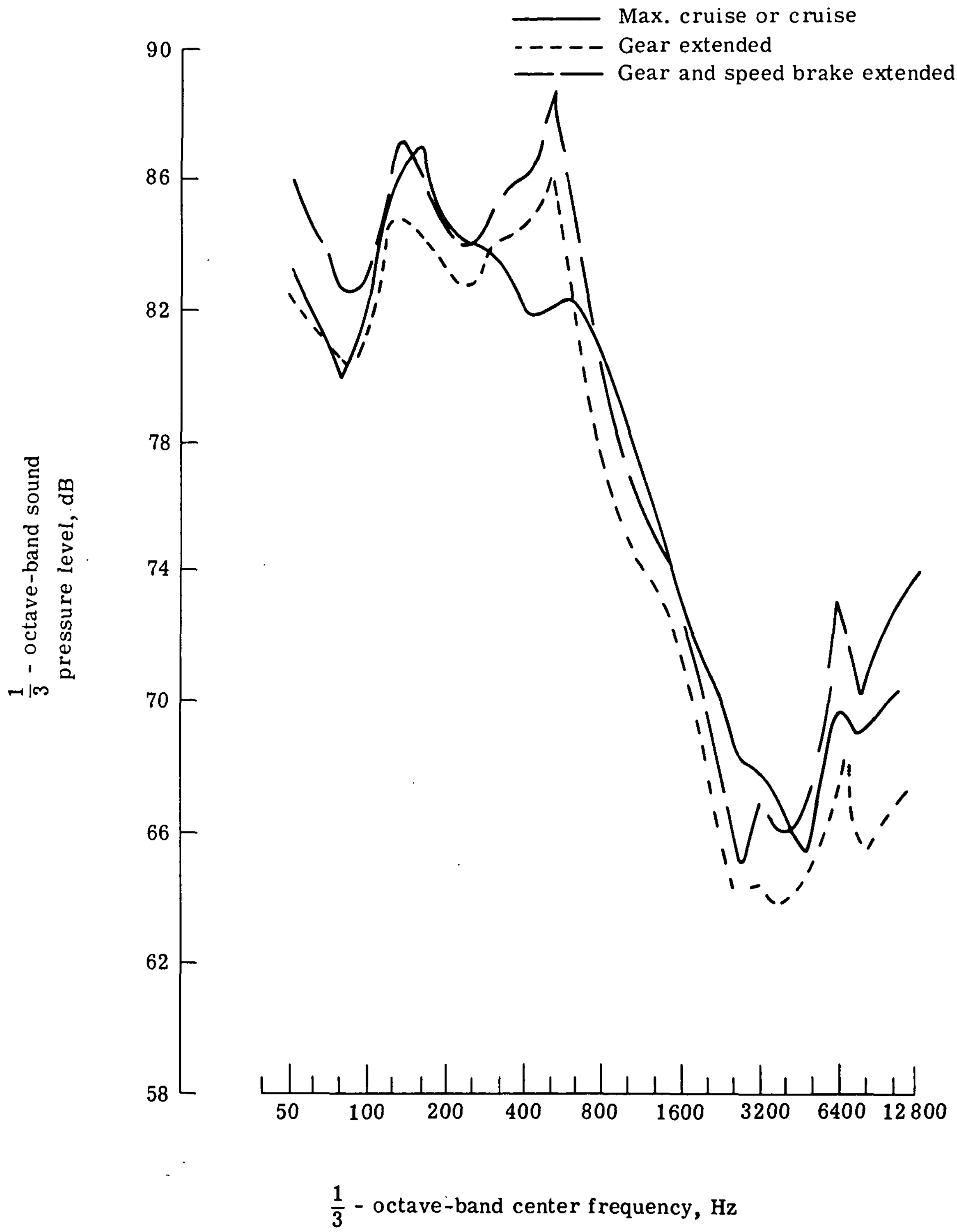


Figure D2.- Typical noise spectra.

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TABLE I.- CHARACTERISTICS OF THE NASA TWIN-JET AIRPLANE

Maximum take-off weight, kg (lb)	44 362	(97 800)
Maximum landing weight, kg (lb)	40 688	(89 700)
Maximum zero full weight, kg (lb)	38 556	(85 000)
Operating empty weight, kg (lb)	30 845	(68 000)
Wing span, m (ft)	28.35	(93)
Overall length, m (ft)	28.65	(94)
Overall height, m (ft)	11.28	(37)

TABLE II. - QUESTIONNAIRE # 1

Subject #: ________ Flight #: ________ Segment #: ________

Please indicate your overall reaction to the previous flight segment by checking one of of the descriptions below.

☐ Very comfortable ☐ Comfortable ☐ Acceptable

☐ Uncomfortable ☐ Very uncomfortable

On the page below, we would like you to rate the following individual Features of the preceding ride segment. Along a five point scale ranging from "comfortable" to "uncomfortable," you will circle number 1, 2, 3, 4, or 5; the lower the number, the more "comfortable" your judgement - - - conversely, the higher the number you circle, the more "uncomfortable" your judgement of that item.

	Comfortable					Uncomfortable
Noise	1	2	3	4	5	
	Comfortable					Uncomfortable
General vibration	1	2	3	4	5	

TABLE III.- QUESTIONNAIRE # 2

Subject #: ____________ Flight #: ____________ Segment #: ____________

The objective of this questionnaire is to identify the needs and desires of passengers so that future transportation systems may increase passenger satisfaction.

1. Age ____ Weight ____ lbs Height ____ ____"

2. Sex: ○ M ○ F

3. Primary occupation: (Check one)
   - ○ Homemaker
   - ○ Student
   - ○ Sales
   - ○ Manager, Official, Executive
   - ○ Craftsman, Mechanic
   - ○ Secretary, Clerical
   - ○ Professional
   - ○ Other (specify) ____________________

4. Approximate total household income (before taxes):
   - ○ Under $10,000
   - ○ $10,000-20,000
   - ○ $20,000-30,000
   - ○ $30,000 or more

5. What is the primary purpose of this trip? (Check one)
   - ○ Company business
   - ○ Personal business
   - ○ Pleasure

6. About how many times have you traveled by this mode of transportation?
   - ○ 0 (This is my first trip.)
   - ○ 1-3
   - ○ 4 or more

TABLE III.- Continued

7. How do you feel about traveling by this mode of transportation?
    - ○ I like it.
    - ○ I have no strong feelings.
    - ○ I dislike it.
    - ○ I use this mode of transportation because I have to.

8. Indicate the importance of each of the following factors in your choice of way to travel (this trip).

	Not Important	Moderately Important	Very Important
Trip cost	○	○	○
Time-saving	○	○	○
On-time arrival and departure	○	○	○
Onboard services	○	○	○
Ride comfort	○	○	○
Convenience (door-to-door)	○	○	○
Ability to read or write	○	○	○

9. Check the box which indicates how much time during this trip you spent doing each of the following:

	None	Some	Most
Reading	○	○	○
Writing	○	○	○
Talking	○	○	○
Looking out the window	○	○	○
Dozing	○	○	○
Thinking	○	○	○
Drinking or eating	○	○	○

Were any of the above difficult to perform? ____________________

TABLE III.- Continued

10. Please indicate your overall reaction to this flight. (Check one.):

- ○ Very comfortable
- ○ Comfortable
- ○ Neutral
- ○ Uncomfortable
- ○ Very uncomfortable

Comment ______________________________

11. Check the box which indicates your feelings about each of the following items on this flight.

	Not Uncomfort-able	Somewhat Uncomfort-able	Very Uncomfort-able
Lighting	○	○	○
Pressure (on ears)	○	○	○
Noise	○	○	○
Odors (other than tobacco smoke)	○	○	○
Presence of tobacco smoke	○	○	○
Temperature	○	○	○
Ventilation	○	○	○
Workspace	○	○	○
General vibration	○	○	○
Sudden jolts	○	○	○
Up and down motion (bouncing)	○	○	○
Backward and forward motion	○	○	○
Side-to-side motion (rolling and sway)	○	○	○
Sudden descents	○	○	○
Turning	○	○	○
Other (comment)			

TABLE III. - Concluded

12. Indicate your reaction to each of the following statements about your seat.

	Agree	Disagree	Strongly Disagree
It has enough leg room.	○	○	○
Its firmness is satisfactory.	○	○	○
It is wide enough.	○	○	○
Its shape is satisfactory.	○	○	○
Its adjustment is satisfactory.	○	○	○

13. Specify your seat location:

(Check one)
- ○ Ahead of the wing
- ○ Over or under the wing
- ○ Behind the wing

(Check the first which applies.)
- ○ Window seat
- ○ Center seat
- ○ Aisle seat

Was an adjacent seat occupied? ○ Yes ○ No

14. After experiencing this flight, I would:
(Check only one.)
- ○ be eager to take another flight
- ○ take another flight with confidence
- ○ take another flight, but with some doubt
- ○ prefer not to take another flight
- ○ not take another flight

15. Have you taken airsickness medication? Previously ○ Yes ○ No
This flight ○ Yes ○ No

Did you experience any symptoms of airsickness on this flight? ○ Yes ○ No

16. General comments ______________________________

TABLE IV.- NOISE AND VIBRATION LEVELS

AND ASSOCIATED SUBJECTIVE RATINGS

rms vibration level, g units		Noise level, dB(A)	Average ratings		
Vertical	Lateral*		Noise, R_n	Vibration, R_v	Overall, R_o
0.0285	0.0056	86	3.00	2.15	2.46
.0312	.0102	93	2.31	2.00	1.92
.0316	.0087	86	3.33	2.50	2.75
.0319	.0075	91	3.46	2.54	2.85
.0403	.0064	95	3.64	2.55	2.73
.0447	.0076	88	2.62	2.62	3.07
.0448	.0083	90	3.77	2.82	2.92
.0486	.0065	81	1.62	1.31	1.77
.0506	.0054	87	2.54	2.08	2.54
.0536	.0073	94	4.15	2.69	3.53
.0549	.0074	94	3.69	3.23	3.85
.1029	.0091	84	1.77	1.39	1.84
.1161	.0106	94	3.15	1.92	2.85

*Included for reference only (not referred to elsewhere).

TABLE V.- COMPARISON OF MALE AND FEMALE RATINGS

rms vibration, g units	Noise rating, R_n		Vibration rating, R_v		Overall rating, R_o	
	Male	Female	Male	Female	Male	Female
0.0285	3.4	2.5	2.1	2.2	2.8	2.0
.0312	2.4	2.2	2.3	1.7	2.1	1.7
.0316	3.7	3.0	2.7	2.3	3.5	2.2
.0319	3.7	3.2	2.7	2.3	3.3	2.3
.0403	4.0	3.3	2.8	2.3	3.6	2.0
.0447	2.9	2.3	2.7	2.5	3.1	3.0
.0448	3.6	3.8	2.7	3.0	3.0	2.8
.0486	1.9	1.3	1.4	1.2	2.0	1.5
.0506	2.6	2.5	2.1	2.0	2.4	2.7
.0536	4.4	3.8	2.6	2.7	3.6	3.5
.0549	3.9	3.5	3.0	3.5	4.1	3.5
.1029	1.9	1.7	1.6	1.3	1.9	1.8
.1161	3.4	2.8	2.1	1.7	2.9	2.5
$t_{critical}$		2.179		2.179		2.179
Paired t		5.42		1.78		3.48
Statistically significant		Yes		No		Yes

TABLE VI.- COMPARISON OF RATINGS DUE TO EXPERIENCE

rms vibration, g units	Noise rating, R_n		Vibration rating, R_v		Overall rating, R_o	
	Exp.	Inexp.	Exp.	Inexp.	Exp.	Inexp.
0.0285	3.3	2.3	2.1	2.3	2.7	2.0
.0312	2.3	2.3	2.1	1.8	2.2	1.8
.0316	3.4	3.3	2.5	2.5	2.9	2.5
.0319	3.4	3.5	2.4	2.8	3.2	2.5
.0403	3.9	3.5	2.6	2.5	3.0	2.3
.0447	2.7	2.5	2.9	2.0	3.1	3.0
.0448	3.7	3.8	2.8	3.0	3.1	2.8
.0486	1.8	1.5	1.3	1.3	1.7	2.0
.0506	2.7	2.3	2.2	1.8	2.6	2.5
.0536	4.1	4.2	2.9	2.3	3.6	3.3
.0549	3.6	4.0	3.2	3.3	3.9	3.8
.1029	1.9	1.5	1.7	1.0	2.1	1.8
.1161	3.3	2.8	2.0	1.8	3.0	2.5
$t_{critical}$	2.179		2.179		2.179	
Paired t	2.01		1.65		4.12	
Statistically significant	No		No		Yes	

L-73-19

Figure 1.- Large twin-jet airplane used in flight study of subjective response.

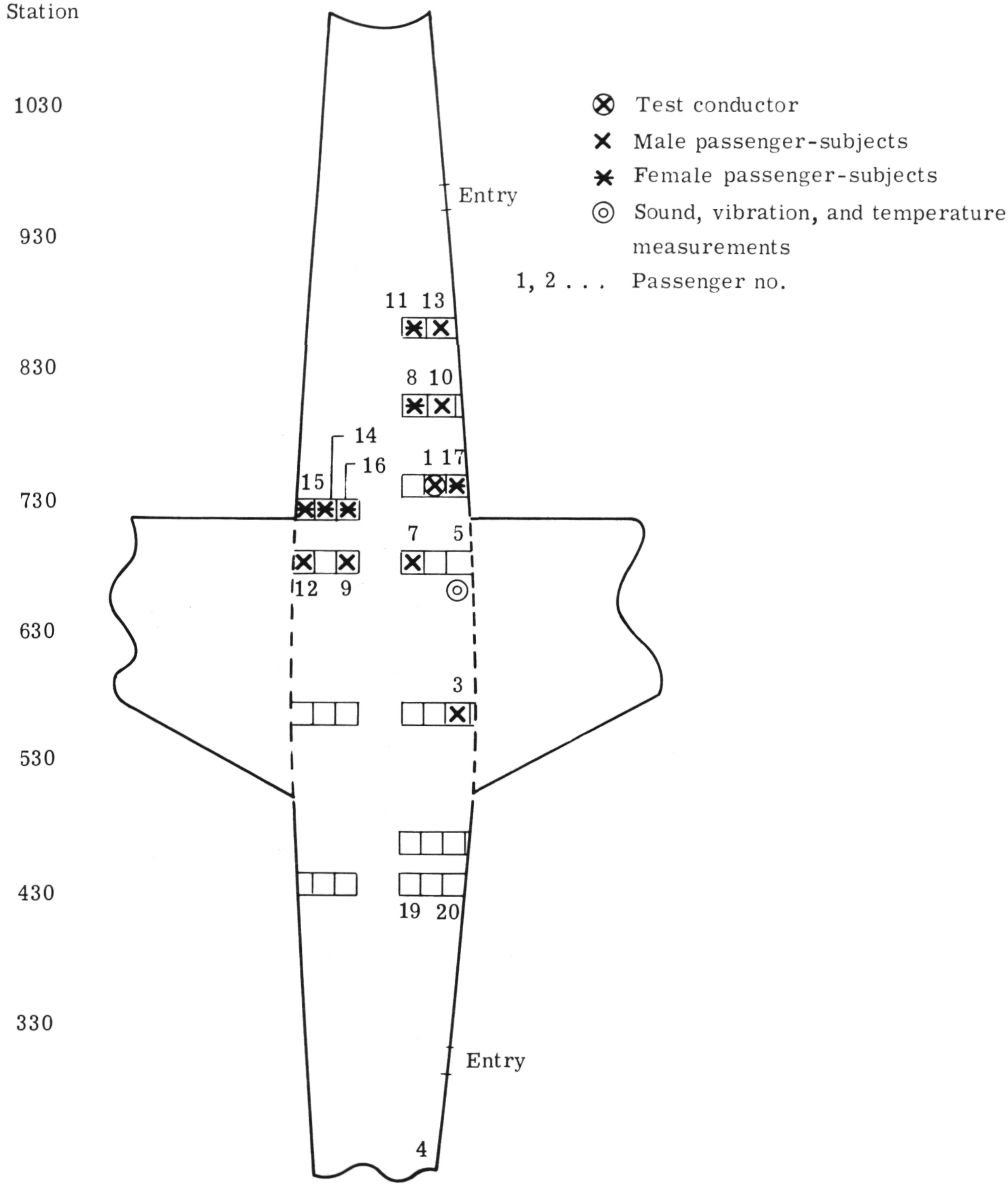

Figure 2.- Location of passenger-subjects and measuring equipment.

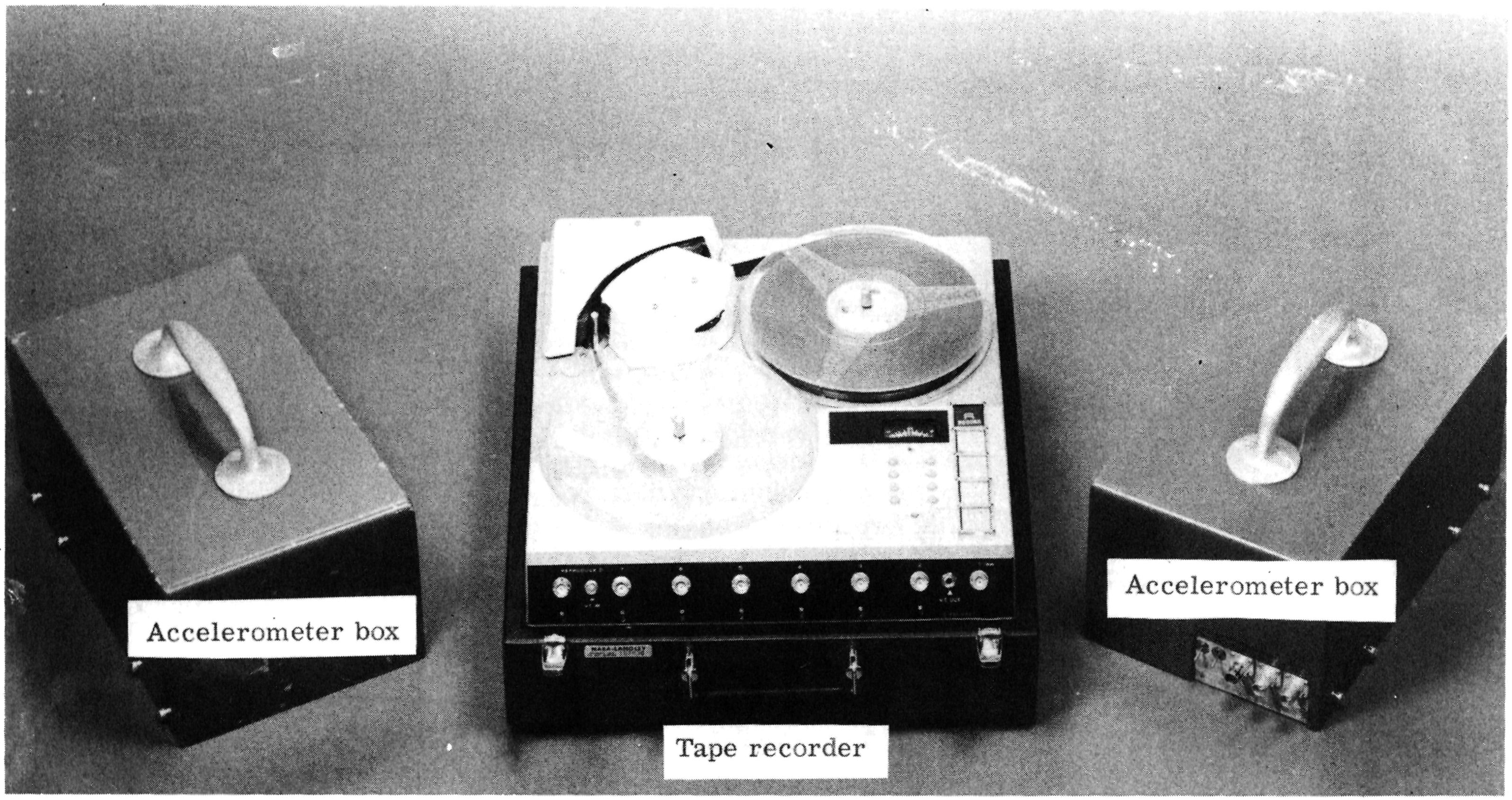

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Figure 3.- Equipment for measuring and recording vibration.

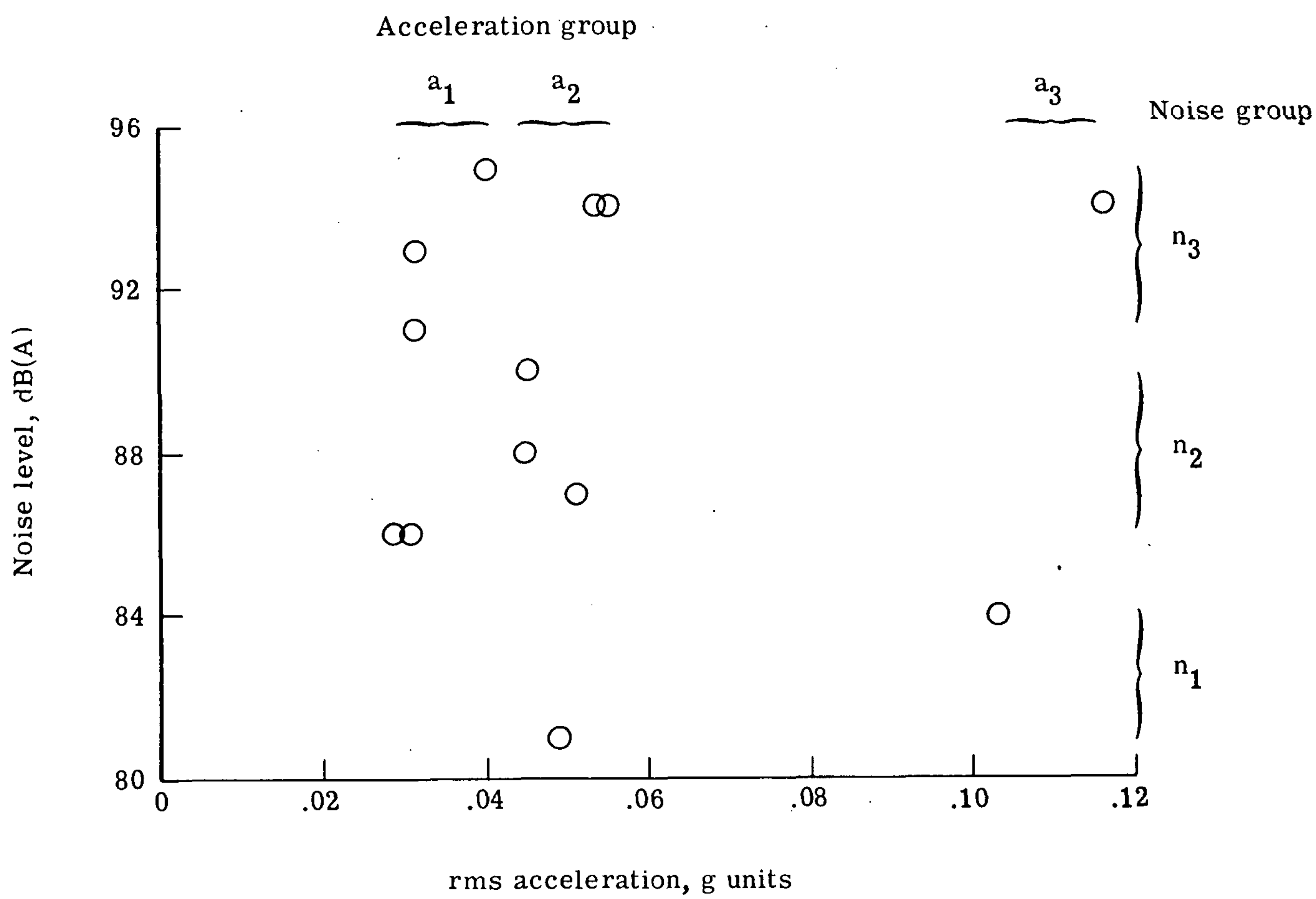


Figure 4.- Ranges of vertical (<30 Hz) vibration and noise levels. r = 0.038.

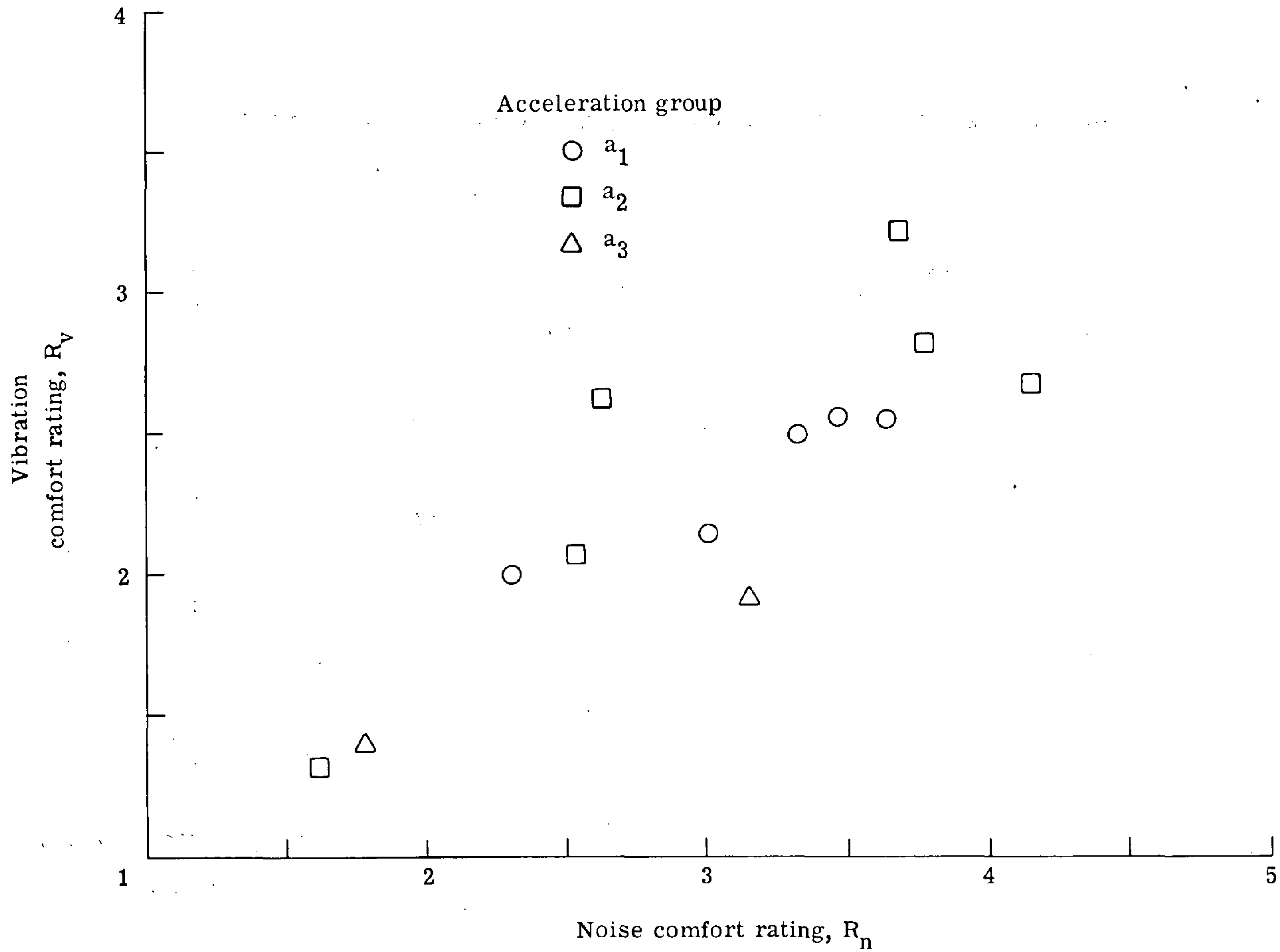


Figure 5.- Correlation of vibration comfort rating with noise comfort rating for constant acceleration levels. $r = 0.854$.

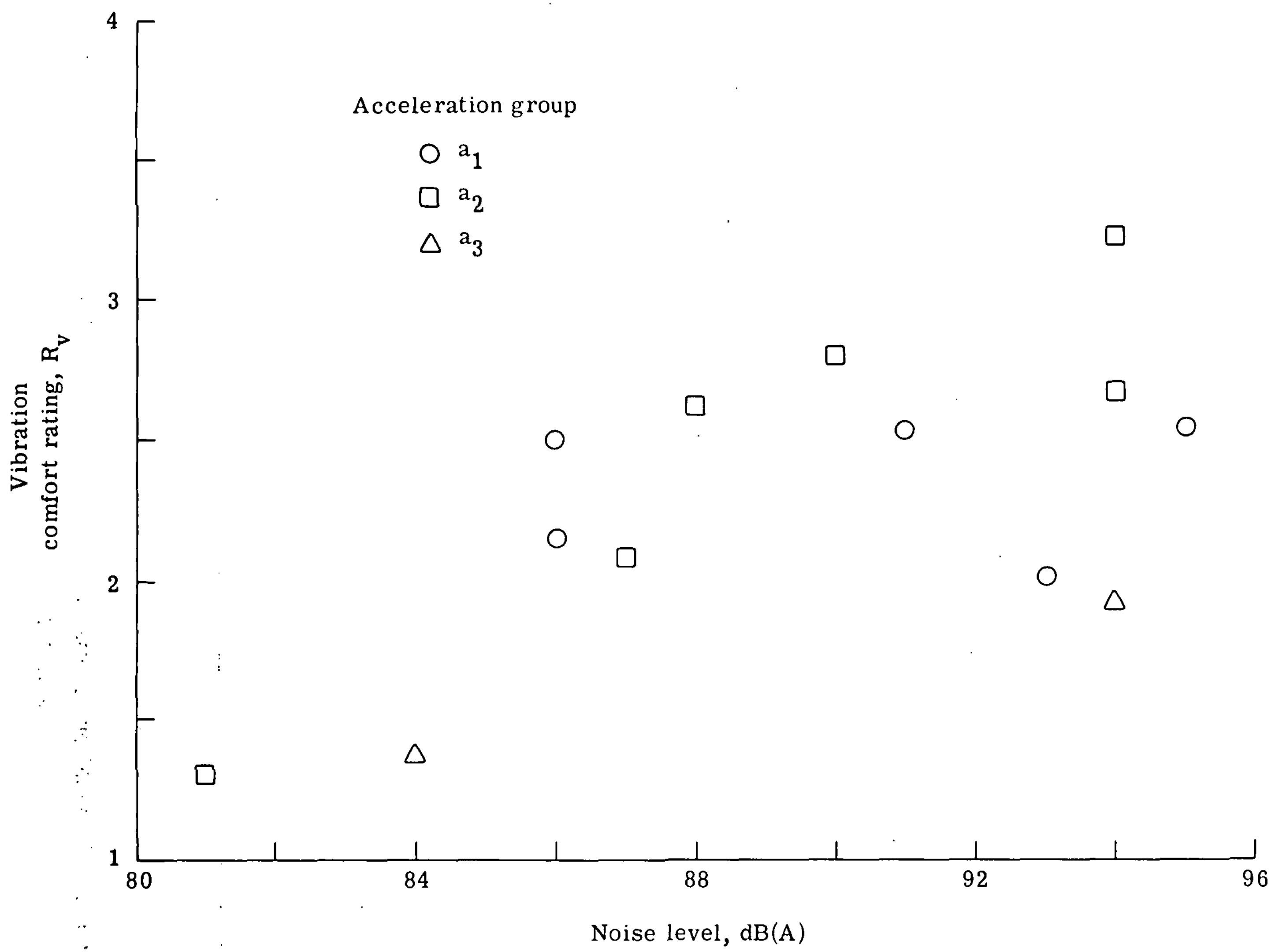


Figure 6.- Correlation of vibration comfort rating with noise levels for constant acceleration levels. $r = 0.622$.

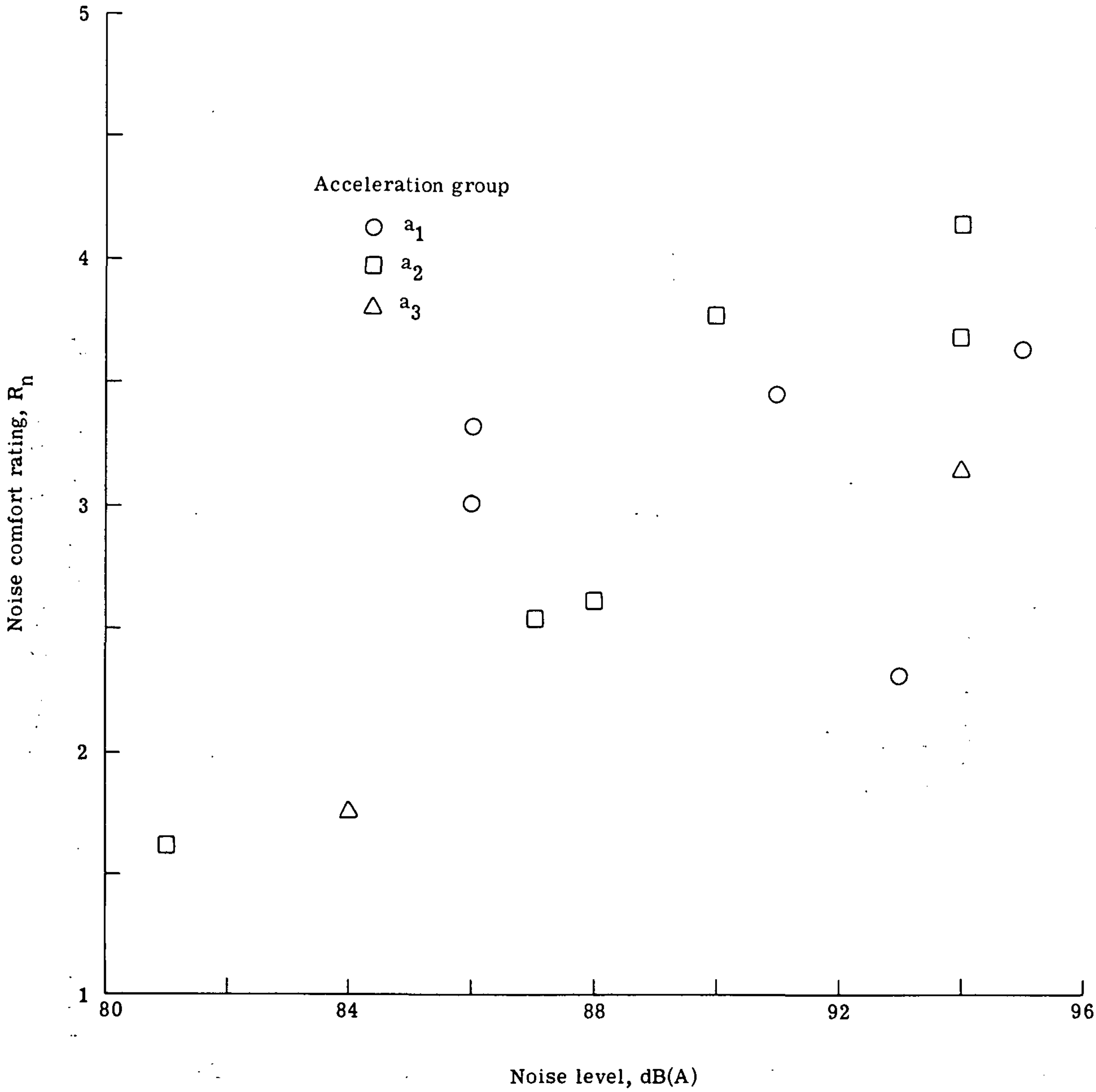


Figure 7.- Correlation of noise comfort rating with noise levels for constant acceleration levels. $r = 0.715$.

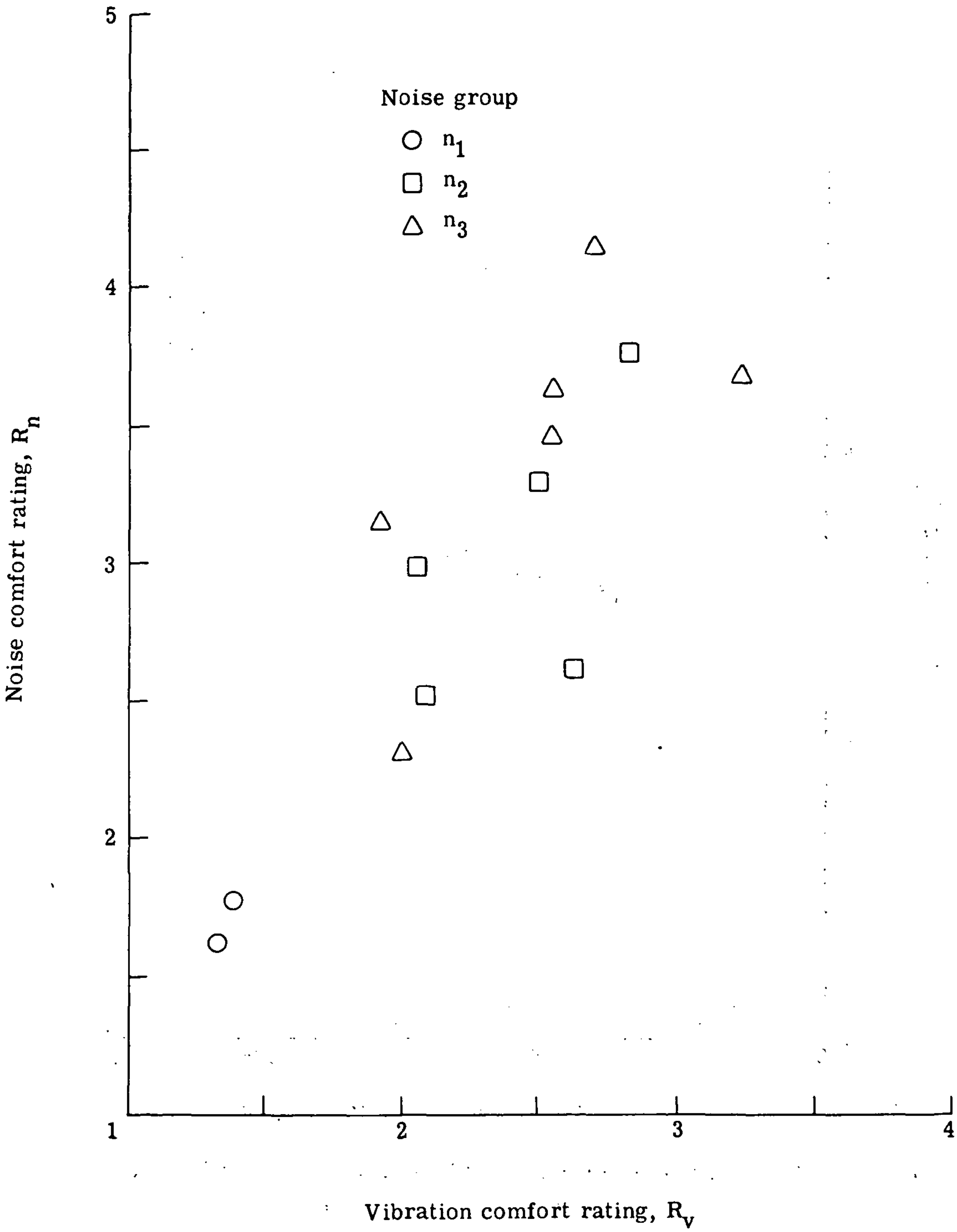


Figure 8.- Correlation of noise comfort rating with vibration comfort rating for constant noise levels. $r = 0.854$.

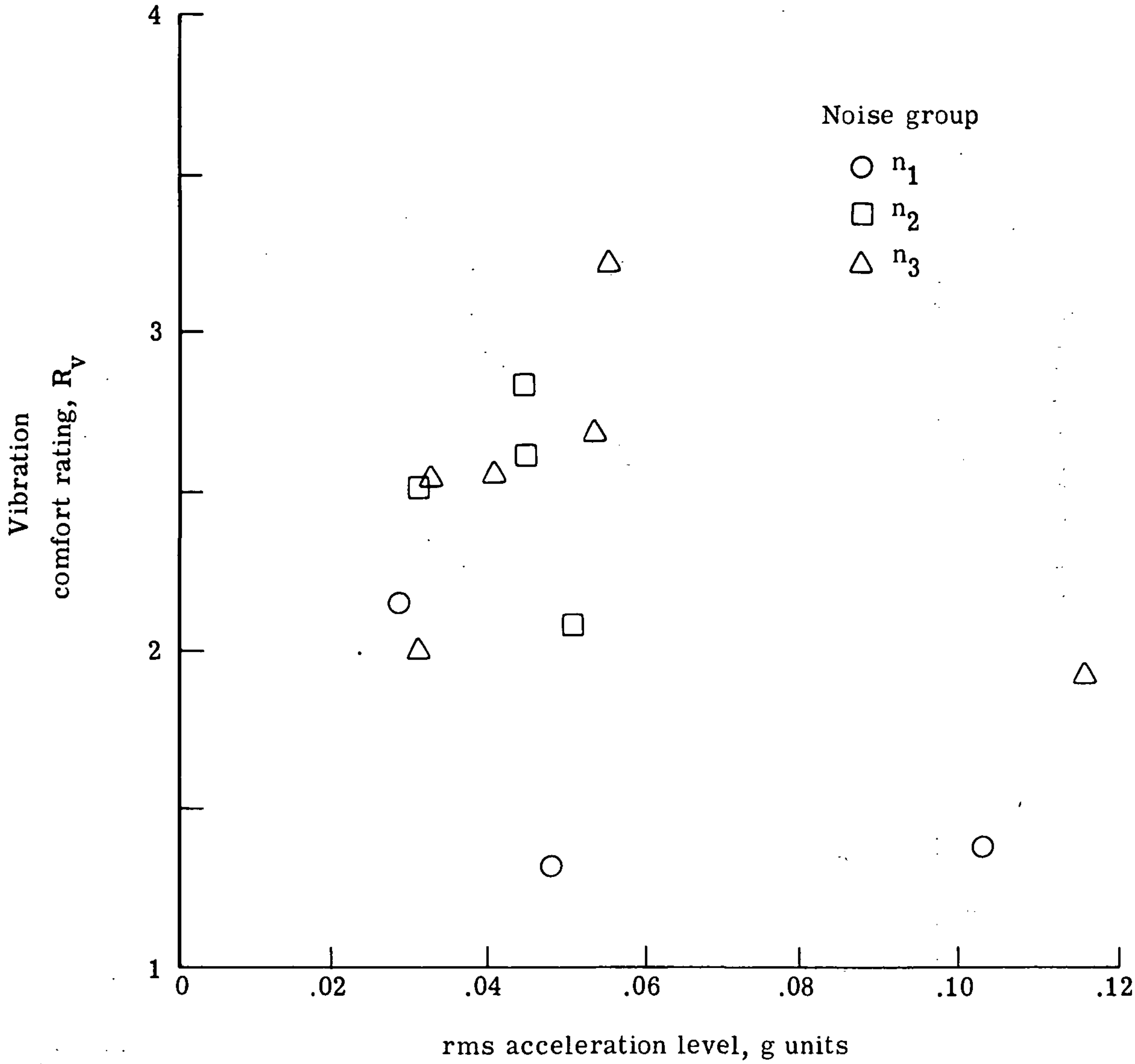


Figure 9.- Correlation of vibration comfort rating with acceleration level for constant noise levels. $r = -0.401$.

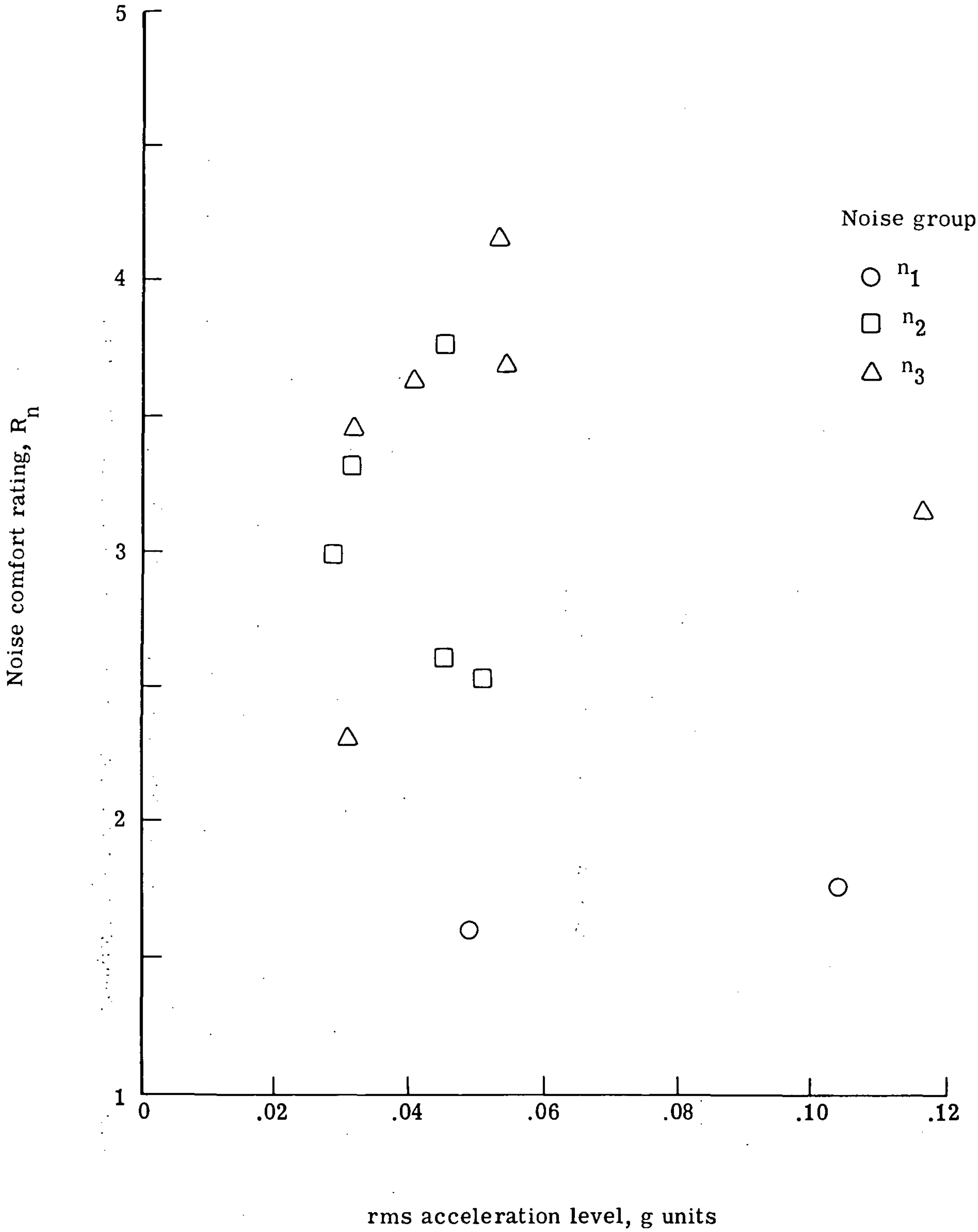
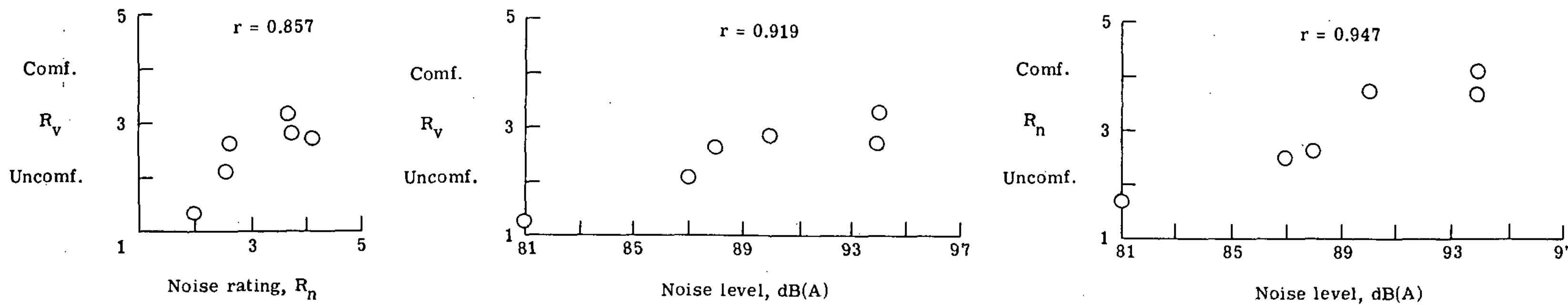
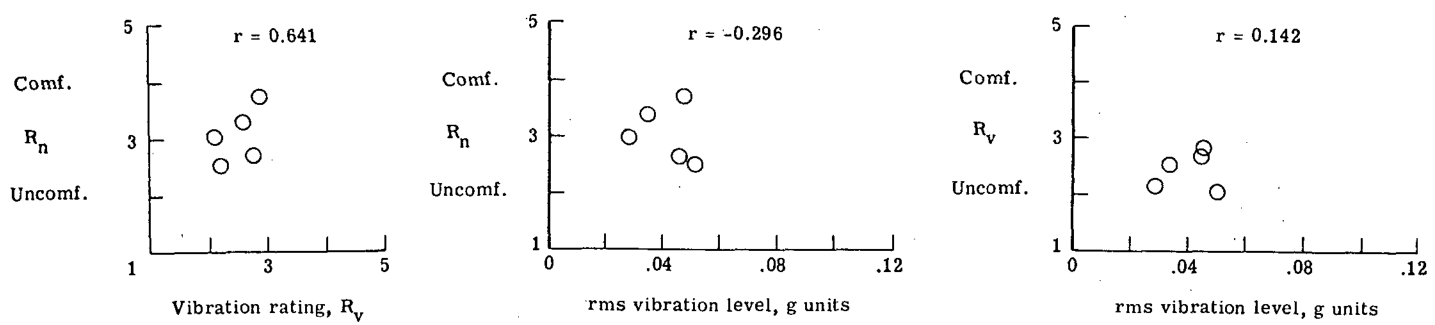


Figure 10.- Correlation of noise comfort rating with acceleration level for constant noise levels. r = -0.219.



(a) Constant vibration level. $g_{rms} = 0.0498 \pm 0.0051$.



(b) Constant noise level. dB(A) = 88 ± 2.

Figure 11.- Composite correlations of noise and vibration ratings with environments.

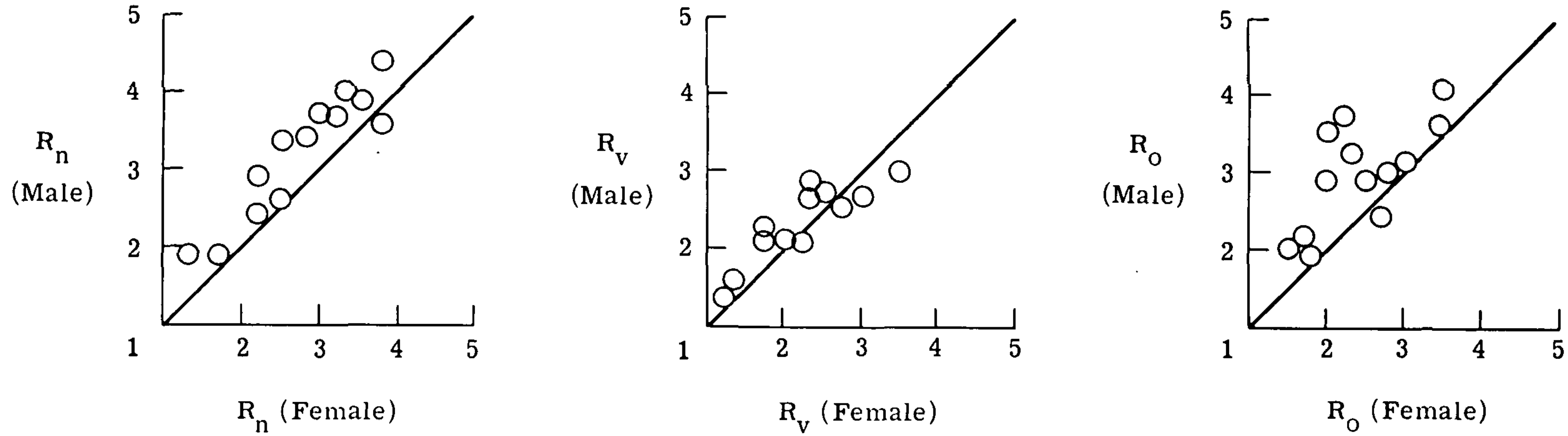


Figure 12.- Comparison of ride comfort ratings by male and female passengers.

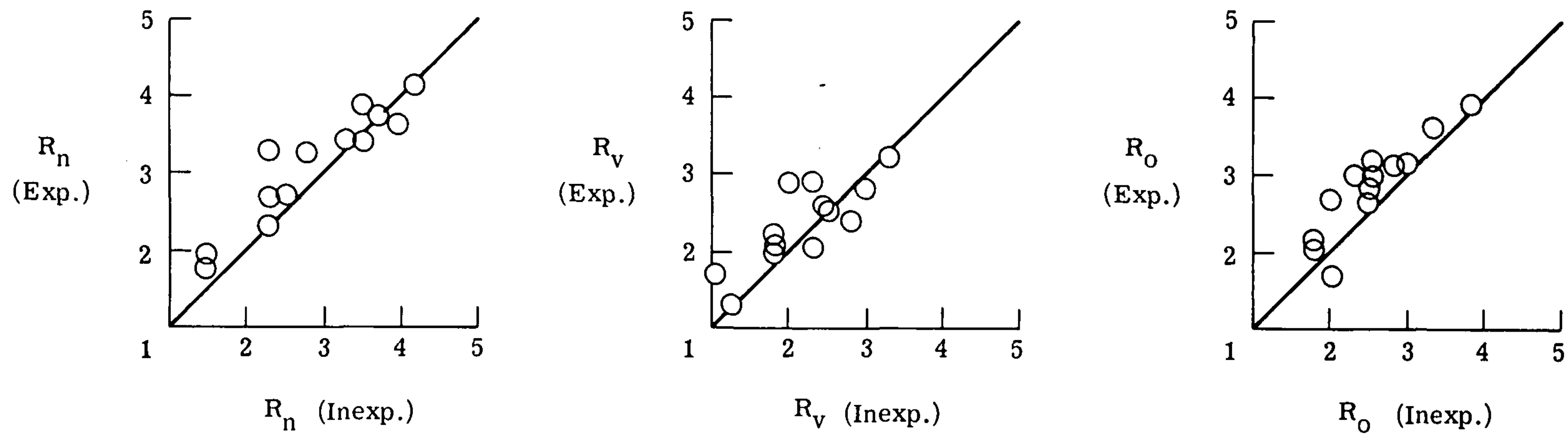


Figure 13.- Comparison of ride comfort ratings by experienced and inexperienced passengers.

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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